MOOSE COLLISIONS WITH VEHICLES AND TRAINS IN NORTHEASTERN MINNESOTA

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ABSTRACT: A minimum of 33 and 26 moose (*Alces alces*) collisions occurred on highways and railways in northeastern Minnesota during 1993 and 1994, respectively. This represented <1% of the regional moose population estimate and 9-11% of the total annual harvest for the same years. Frequency of collisions increased from February through June, was greatest from June through September, then declined and remained constant from October through January. Vehicle traffic volume explained 59% of the monthly variation in frequency of moose collisions ($P = 0.04$). More (69%, $P < 0.05$) moose were struck by vehicles at night than during the day. Frequency of moose-vehicle collisions was similar between sexes ($P > 0.05$), as was the number of vehicle collisions that involved adults or calves ($P > 0.10$). Intensive management (e.g. fencing) to reduce the current number of moose collisions cannot likely be justified economically, however, additional placement of signs and public awareness programs should be considered. Moose mortality from vehicle collisions should also be considered in relation to harvest management. I recommend improvement and integration of existing and future moose collision data to more accurately monitor its occurrence in relation to harvests, population trends, and potential future management activities to reduce frequency of collisions.

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Collisions with vehicles can be a major mortality factor of moose, particularly where moose winter range is intersected by heavily-travelled highways (Bangs *et al.* 1989). Del Frate and Spraker (1991) reported up to 366 moose killed annually on the Kenai Peninsula between 1977 and 1991. Between 400 and 1,200 moose have been estimated to die annually in vehicle collisions in British Columbia (Child *et al.* 1991). In Newfoundland, over 400 moose-vehicle collisions have occurred annually in recent years (Oosenbrug *et al.* 1991).

Although less widespread, moose-train collisions can also present a large source of mortality. Child *et al.* (1991) reported an average of 200 moose-train collisions in British Columbia from 1988-1990. Between 1980 and 1988, 262 moose-train collisions occurred along a 92.2 km section of railway in Norway (Andersen *et al.* 1991). Moose-train collisions along 756 km of railway in Alaska has ranged from 9 to 725 annually (Modafferi 1991).

Moose collisions with vehicles and trains have resulted in significant economic loss and human injury or death. Vehicle damage and value of meat lost from vehicle-killed moose is estimated at >$1.6 million annually in Newfoundland (Oosenbrug *et al.* 1991). Property damage in Ontario during 1977-1980 was estimated at $1,500 per accident (E. R. Thomas, unpubl. data *in* Fraser and Hristenko [1982]). From 5 to 20 human deaths and 500 additional injuries are reported in Sweden each year (Lavsund and Sandegren 1991). Moose collisions with vehicles can also effect harvest quotas. In British Columbia, regional reductions in annual harvest quotas in response to moose collisions have ranged to 20% (Child *et al.* 1991), further documenting that moose-vehicle collisions can be an important form of mortality.

Moose-vehicle and moose-train relationships have been reported in many areas throughout their range (Child 1983, Del Frate and Spraker 1991, Lavsund and Sandegren

1991, Oosenbrug *et al.* 1986, Alexander 1993, Morris and Elowe 1993, Vecellio *et al.* 1993), however, no comparable data has been summarized for Minnesota. The objective of this study was to determine the frequency and timing of moose-vehicle collisions in relation to moose populations, harvest management, and potential management activities for collision reduction in northeastern Minnesota.

STUDY AREA AND METHODS

The study was conducted in a four-county area (21,800 km^2) of northeastern Minnesota which comprised 21,800 km^2 (Fig. 1). Within the study area were 13,375 km of public roads and a minimum of 1,200 km of railways. Estimates of the number of kilometers of public roads and number of kilometers vehicles travelled on public roads were obtained from the Minnesota Department of Public Safety. The number of kilometers of railways was estimated from 1:50,000 topographic maps.

Moose were distributed throughout the study area (Fuller 1986; Belant, unpubl. data), with primary range encompassing about 13,500 km^2 in the extreme northern portion. Much of this area is roadless and includes the Boundary Waters Canoe Area Wilderness. Winter aerial moose surveys were conducted

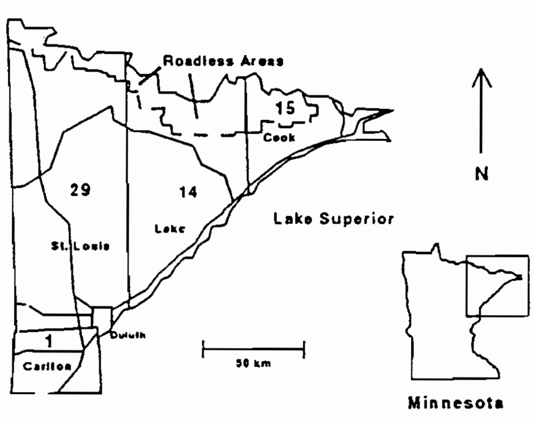

Fig. 1. Location of study area in northeastern Minnesota and number of moose-vehicle and moose-train collisions that occurred by county during 1993 and 1994.

annually by the Minnesota Department of Natural Resources (MDNR) following techniques developed by Gasaway *et al.* (1986). Adult moose were sexed based on antlers or vulval patch (Mitchell 1970); calves were identified based on size. Moose population estimates in primary range during 1992-1993 and 1993-1994 were 4,292 and 6,768, respectively (M. Lenarz, MDNR, 3 March 1994 memorandum).

Data on moose-vehicle collisions was requested during winter 1994-1995 from personnel of the Fond du Lac Ceded Territory and Reservation Enforcement Departments; Minnesota Department of Natural Resources (MDNR), Division of Law Enforcement; 1854 Authority; Cook, Lake, and St. Louis County Sheriff Departments; and Minnesota State Patrol. Agency personnel were requested to provide the date of each moose-vehicle collision, time of day it occurred, sex and age of moose involved, and location of the incident. Time of day moose-vehicle collisions occurred was categorized into six 4-hr periods beginning with 0000-0359.

Information on moose-train collisions was requested of personnel from the Duluth, Missabe, and Iron Range (DMIR); Burlington Northern (BN); Duluth and Northwestern (DN); Duluth, Winnipeg, and Pacific (DWP); and Canadian Pacific (CP) Railroads. Data requested were identical to that requested for moose-vehicle collisions from other sources.

Chi-square analysis was used to compare moose-vehicle collisions by time of day and sex/age classes. Correlation analysis was used to determine the association between frequency of moose-vehicle collisions and traffic volume.

RESULTS

Moose-Vehicle Collisions

Fifty-five moose-vehicle collisions were reported by the respective agencies in 1993 and 1994 combined. Frequency of collisions increased from February through June, was greatest from June through September, then declined and remained constant from October through January (Fig. 2). There was a positive relationship between monthly frequency of moose-vehicle collisions and vehicle traffic volume ($r = 0.59$, $P = 0.04$). Although there was no difference ($x^2 = 3.67$, 5 df, $P > 0.50$) in frequency of collisions among the six time periods (Fig. 3), more ($x^2 = 4.17$, 1 df, $P < 0.05$) moose-vehicle collisions occurred at night than during daylight hours.

Frequency of moose-vehicle collisions was similar between sexes ($x^2 = 3.04$, 1 df, $P > 0.05$), as was the number of vehicle collisions involving adults or calves ($x^2 = 0.50$, 1 df, $P > 0.10$) (Table 1). There were, however, differences in collision frequency between sexes over time. Thirty-six percent of collisions involving males (primarily adults) occurred during September and October in contrast to 19% of females ($n = 36$). In collisions where age and sex of moose were reported ($n = 36$), the percentage of adult males, adult females, and calves was 19.4%, 38.9%, and 41.7%, respectively.

An unknown number of moose were likely also killed on logging and mining roads but were not reported. Although the number of losses cannot be established, anecdotal information from agency personnel suggests that the number of moose killed along these roads may equal the reported number killed (20-30 moose annually).

Moose-Train Collisions

Four of the five railroads contacted did not maintain records regarding moose-train collisions. Personnel from BN, DN, and CP Railroads stated that no moose were struck by their trains during 1993 or 1994 (T. Wester, BN Railroad, pers. commun.; D. Randa, DN Railroad, pers. commun.; D. Izzard, CP Rail,

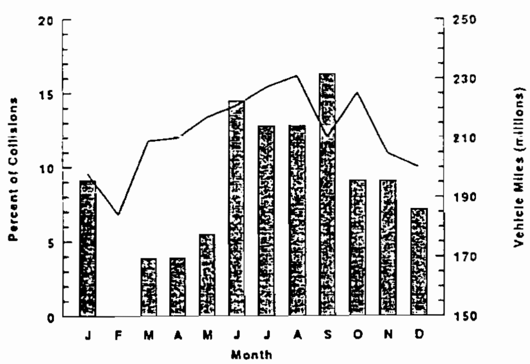

Fig. 2. Percent of moose-vehicle collisions by month (bars) and vehicle miles travelled (line), northeastern Minnesota, 1993-1994.

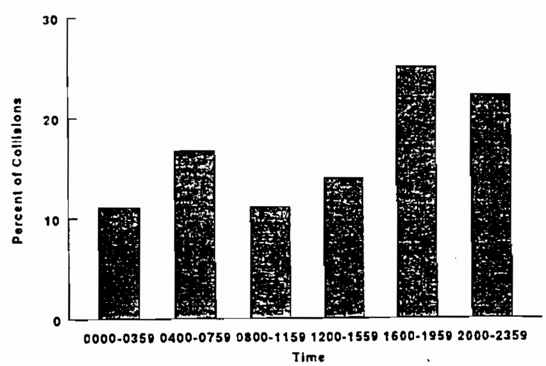

Fig. 3. Percent of moose-vehicle collisions by time of day, northeastern Minnesota, 1993-1994.

Table 1. Number of moose-vehicle collisions in northeastern Minnesota by sex and age class, 1993-1994.

	Male		Female			
Year	Adult	Calf	Adult	Calf	Unknown	Total
1993	4	3	8	5	11	31
1994	3	1	6	6	8	24
Total	7	4	14	11	19	55

pers. commun.). Moose-train collisions on the DMIR Railroad occur infrequently, with no more than 1 or 2 moose killed annually (G. LaValley, DMIR Railroad, pers. commun.). DWP trains collide with 2-3 moose annually (D. Randa, DWP Railroad, pers. commun.). Although DWP personnel do not maintain records of moose-train collisions, each collision is reported to MDNR personnel (D. Randa, DWP Railroad, pers. commun.). MDNR data lists that 4 moose, 2 each in 1993 and 1994, collided with trains. Three of these were adult males, the fourth was an adult female. One of the collisions occurred in May, 2 in June, and the fourth in October. All four of the collisions occurred in Lake County.

DISCUSSION

Moose-Vehicle Collisions

Fifty-nine percent of the monthly variation in moose-vehicle collisions was explained by traffic volume. Positive relationships between traffic volume and frequency of moose collisions have been implied or documented in other studies (Lavsund and Sandegren 1991, Miller and Litvaitis 1992). Although not evaluated in this study, vehicle speed can also increase frequency of moose collisions (Del Frate and Spraker 1991, Lavsund and Sandegren 1991).

The importance of mineral licks to moose has been demonstrated (Best *et al.* 1977). More recently, creation of anthropogenic salt licks by deposition of deicing agents during winter has been exploited by moose and implicated as a major factor in moose-vehicle collisions during snow-free periods (Grenier 1973, Fraser 1979, Fraser and Thomas 1982, Miller and Litvaitis 1992). The relatively high frequency of moose-vehicle collisions from June through October may be explained in part by use of these roadside salt licks. Roadside salt licks occur frequently along major highways in northeast Minnesota (J. Belant, pers. observ.). In addition, sodium and other minerals in roadside licks are present at higher levels than occur in nearby streams and puddles (Miller and Litvaitis 1992).

Although samples are limited, the increased proportion of adult male moose-vehicle collisions during September and October could be a consequence of increased movements or modified behavior in relation to rutting. Greater movements by male moose during the rut have been documented in numerous studies (Van Ballenberghe and Peek 1971, Lynch and Morgantini 1984, Garner and Porter 1990).

The moderately high number of moose collisions that occurred during December and January may be related to snowdepth. Increased snowdepths have reportedly caused moose to use roads and railroad beds, presumably to reduce energetic demands (Del Frate and Spraker 1991, Modafferi 1991). Although moose are less active during winter than summer (Risenhoover 1986, Garner and Porter 1990, Van Ballenberghe and Miquelle 1990), increased use of roads as travel routes would increase the risk of collisions with vehicles.

A larger proportion of moose-collisions occurred during night than during daylight hours. Moose in Newfoundland were most frequently killed during the first few hours after sunset but were most vulnerable during summer near sunrise (Oosenbrug *et al.* 1986). Moose activity can be greater during day or night, presumably related to seasonal changes in forage quality and distribution (Risenhoover 1986). An alternative explanation is reduced driver visibility during night. People have been reported to search suboptimally for moose while driving (Aberg 1981, *in* Lavsund and Sandegren 1991). Thus, the reduction in visibility at night further reduces the ability for individuals to observe moose.

Total economic loss from moose collisions in northeastern Minnesota is considerably lower than in other areas of North America. Using cost estimates developed by

Oosenbrug *et al.* (1991), where the average meat value of a moose is \$1,320 and average vehicle damage is at least \$2,400, I estimate minimum total economic loss at approximately \$85,000 annually. In contrast, annual meat value of vehicle-destroyed moose in Newfoundland is estimated at \$600,000 and vehicle damage is $\geq$\$1 million (Oosenbrug *et al.* 1991). Extrapolating these cost estimates to the Kenai Peninsula resulted in an annual loss of about \$800,000 from 1984 to 1989 (see Del Frate and Spraker 1991).

Several techniques including roadside vegetation clearing, public awareness programs, fencing along roadways, construction of underpasses, one-way gates, highway lighting, and increasing moose harvests in areas of high vehicular traffic have been attempted with varying degrees of success (Del Frate and Spraker 1991, Lavsund and Sandegren 1991, McDonald 1991, Oosenbrug *et al.* 1991). Currently, large-scale invasive management practices (e.g. fencing) to reduce moose-vehicle collisions in northeastern Minnesota may not be justified. However, management including additional placement of moose crossing signs, public awareness programs, and increased moose harvest in areas of high-collision frequency may reduce the rate of collisions.

Moose-Train Collisions

Moose-train collisions in northeast Minnesota occur infrequently. Minimum estimates suggest that only 3 to 5 collisions with trains occurred annually. This contrasts markedly with frequency of moose-train collisions that occur in other areas of moose range (Child 1983, Child *et al.* 1991, Anderson *et al.* 1991, Jaren *et al.* 1991, Modafferi 1991). Although the exact cause for low numbers of moose-train collisions is unknown, potential reasons include slower train speeds, less train traffic, and railways passing through areas of low moose density and non-wintering areas.

Several techniques including ultrasonic warning devices, vegetation removal, and modifying train speed have been attempted to reduce moose-train collisions (Muzzi and Bisset 1990, Becker and Grauvogel 1991, Jaren *et al.* 1991). It would be difficult if not impossible to justify economically any technique to reduce moose-train collisions in northeast Minnesota. The most beneficial management practice at present would be to maintain monitoring of incidents to document whether increases in frequency of collisions occur.

Effects on Local and Regional Populations and Harvests

The estimated number of moose collisions with motor vehicles and trains in northeastern Minnesota during 1993-1994 represented <1% of the regional population annually. Based on distribution of collisions, it is unlikely that moose mortality from vehicle collisions would substantially affect any local population.

The number of reported moose killed by trains and vehicles in northeastern Minnesota represented 9-11% of the total annual harvest for this region (Belant 1995). Child *et al.* (1991) reported 10% of the annual allowable harvest in British Columbia may die from collisions with vehicles and trains. If one considers unreported collisions, the actual percentage may be considerably higher which would increase the importance of considering collision mortality in relation to harvest management. Regional reductions in annual harvest quotas in response to moose collisions have ranged to 20% in British Columbia (Child *et al.* 1991). In Newfoundland, moose mortality from collisions with vehicles can equal harvest (S. M. Oosenbrug, pers. commun.).

Reporting Moose Collisions

Currently, there is no standardized data collection for documenting moose collisions in northeastern Minnesota. To improve our knowledge and understanding of moose collisions with vehicles and trains, I recommend that agencies adopt standardized collection techniques to improve data quality and compatibility. At minimum, data collected should include date of collision, time of day, sex and age of moose involved, and location of the incident. This information should be integrated into a single data base to more accurately quantify collision incidents and made available to all agency personnel.

There is potential for using moose-vehicle collision data to develop indices to monitor population trends (Alexander *et al.* 1992, Hicks 1993). For example, 59% of the variation in moose-vehicle collisions during this study was explained by traffic volume. Indices between vehicle collisions and traffic volume have also been developed for white-tailed deer (*Odocoileus virginianus*) (Bellis and Graves 1971, McCaffery 1973, Culbertson and Stoll 1990 *in* Hicks 1993). Documenting locations of moose-vehicle collisions or moose sightings would aid in determining areas which may require increased management efforts. Development of these or other techniques would increase our understanding of mechanisms involving moose-vehicle collisions and improve our abilities to reduce them.

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